

Abstract

An organic Rankine cycle (ORC) modifies the Clausius-Rankine cycle of the steam power plant by employing organic working fluid (or low-boiling working fluid) instead of water. While ORC technology is nowadays well-established in numerous applications, it still presents unexplored potential for further development, particularly in its ability to efficiently utilize intermittent and fluctuating heat sources. This dissertation conducts an analysis of the low-boiling working fluid expansion process and investigates how this process affects the efficiency of various ORC configurations (e.g., partially evaporated ORC, basic ORC, and ORC with a superheater). The study includes theoretical analysis and modeling simulations to evaluate the impact of this expansion on ORC efficiency using different working fluids. These analyses also compare different ORC systems with alternative thermodynamic cycles, namely the trilateral flash cycle and the transcritical power cycle. Moreover, an experimental investigation into the expansion process of low-boiling working fluids in an ORC system was carried out using a multi-vane volumetric expander. Further research predicted the wet isentropic efficiency of the two-phase expansion process using experimental data and artificial intelligence. The dissertation concludes by exploring the practical applications of volumetric expanders in ORC systems. Some results that are part of this dissertation demonstrate that incorporating a two-phase expansion system significantly enhances the adaptability of ORC systems to manage fluctuating low- and medium-temperature heat sources across several fields, including waste heat recovery, geothermal power systems, cold energy utilization, district heating systems, and Carnot batteries.

Keywords: organic Rankine cycle, phase equilibria, partially evaporation, two-phase expander